Climate Change & Animals

Unit 1

Student Magazine

Climate Change & the Marine Environment

Earth's surface is covered by water, and the ocean holds more than 97% of the water on Earth. Through its role in the water and carbon cycles, the ocean is a major contributor to many of Earth's processes. Additionally, the ocean hosts some of the most diverse ecosystems on Earth and serves as an accessible setting for transportation and recreation.

Now, as a consequence of global warming and the resulting climate change, the ocean is undergoing changes of its own. Water temperatures, sea levels, and ocean acidity are all rising, putting at risk all of the animals that live in or near the ocean—polar bears, whales, seals, fish, penguins, turtles, and even humans.

Ocean Processes at Work

Ocean currents carry water and transport heat over thousands of miles. **Surface currents** are caused by wind blowing on the surface of the ocean. Beneath the surface, differences in the sea water's **density**, which is determined by the water's temperature and **salinity**, cause **convection currents**. Warm water and less salty water tend to rise, while cold water and saltier water will tend to sink. Generally, warm, fresh water will float, while cold, salty water will sink. However, this is not always the case. In some places, the wind is strong enough to push ocean water away from an area and pull deep, cold, nutrient-rich water to the surface in a process called **upwelling**. Most upwelling occurs close to coastlines.

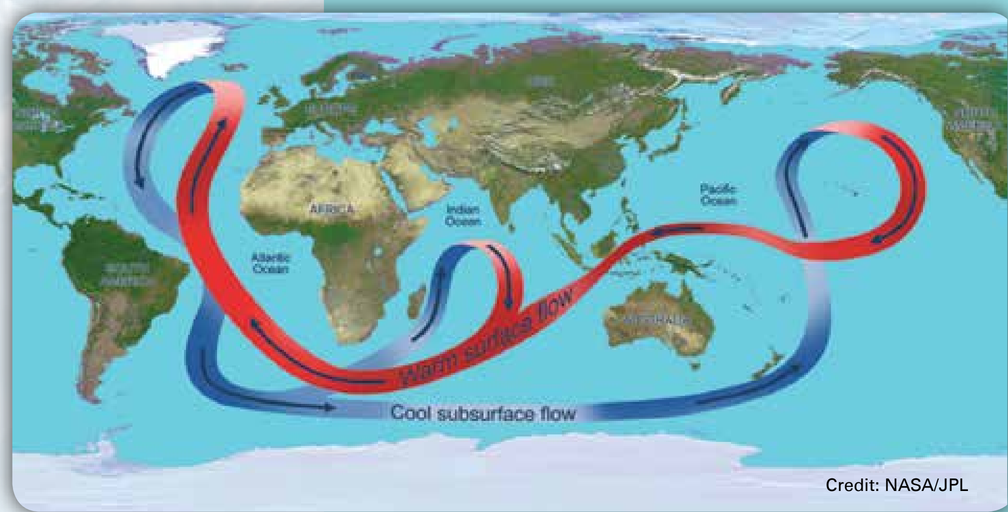
The Great Conveyor Belt

A large current called the Global Conveyor Belt moves water around the Earth, cycling nutrients and carbon dioxide along with it. Unlike surface currents, this deep current moves very slowly. It's been suggested that it takes about 1,000 years to complete the full path.

It all begins in the North Atlantic Ocean, where cold, Arctic sea water freezes to create sea ice. As the water freezes, the salt molecules are forced out, back into the increasingly salty, bitter cold sea water. As the density of the water increases, the water begins to sink and starts its long ride on the Global Conveyor Belt.

The current then travels south along the floor of the Atlantic until it reaches Antarctica, where it is recharged by the formation of sea ice and cold, salty water. From there, the current splits; one part turns north into the Indian Ocean and the rest enters the Pacific Ocean, where it continues north all the way to Alaska.

As the water warms, it rises, turns around along the coast, and heads back towards the equator and beyond, before returning again to the North Atlantic, where the cycle continues.



Credit: NASA/JPL

Evaporation from the ocean surface transfers fresh water into the atmosphere as **water vapor**. As rising water vapor cools, it condenses into tiny droplets of water and forms clouds. The water later returns to the surface as rain or snow. Water that falls on land flows back to the ocean as runoff, bringing with it nutrients, minerals, and pollutants.

But the ocean and the atmosphere share more than water. They also exchange carbon and heat. As the amount of carbon dioxide (CO_2) in the atmosphere increases, more carbon is absorbed into the ocean. And as air temperatures rise, the ocean also absorbs more heat.

Nearly all of the ocean's processes are being affected by climate change. Ocean currents are changing. Evaporation is speeding up as the temperature rises. Ocean acidity is increasing as the ocean absorbs more carbon. And rising temperatures are causing other changes within the ocean.

The ocean's convection currents are driven by differences in the density of sea water. When something happens to change the density of the water (through changes in temperature or salinity), the currents are affected. For example, fresh water from melted ice near the poles dilutes the cold water, making it less likely to sink—remember, fresh water will tend to float over salty water, everything else being equal. Flood waters pouring into the ocean have a similar effect.

The increased speed and quantity of evaporation is causing changes to global weather patterns, and having a significant effect on the land. With more heat and water driving them, hurricanes and tropical storms have become larger and stronger, and more intense monsoons and storm precipitation have caused disastrous flooding.

Increasing ocean acidity is changing the ocean's chemistry. Research is currently underway to determine the effects of these changes on the marine ecosystem.

Warmer ocean temperatures are a major factor in rising sea levels. Global sea levels are rising as the result of **thermal expansion** of warming sea water and the melting land-based ice, each contributing about half of the sea level rise since 2003.

Rising sea levels, like precipitation on land, are affecting different places to different degrees. Over the last century, sea levels in some locations in Sweden and Finland have fallen by as much as 0.3 inches (8 millimeters) per year; stayed nearly the same in some locations in Greece, Argentina, Ireland, Canada, and the Philippines; and have risen by more than 0.24 inches (6 millimeters) per year in particular locations in Japan and Georgia.

The Effect of the Changing Ocean on Marine Animals

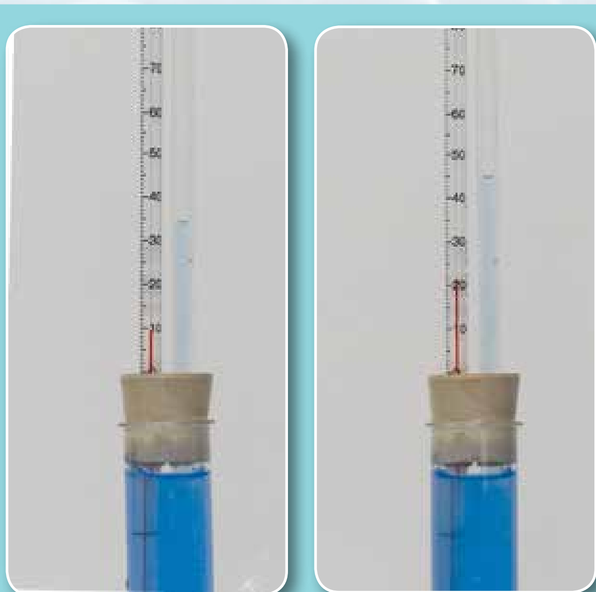
The effects of climate change in the ocean have the power to alter all life on Earth. And it all starts with some of the smallest plants on the planet.

Phytoplankton are small, typically microscopic, free-floating plants that use energy from the sun to build molecules, including the nutrients that form the basis of the entire ocean food web. They grow best in the

Thermal Expansion

If you have ever run the too-tight-to-open metal lid of a jar under hot water to loosen it, you've used thermal expansion to your advantage. As the metal lid of the jar gets warmer, it expands slightly and becomes just enough looser to make the jar easier to open. Thermal expansion is the tendency of most solids, liquids, and gases to expand as their temperature increases.

Water, including sea water, is also subject to thermal expansion. As water warms, it takes up more space. The experiment at right uses colored water to show how much the water expands as it warms from 49°F (9.5°C) to 70°F (21°C). Although the ocean is not likely to warm by that much, it's easy to imagine how even a small amount of expansion across the vast ocean could result in measurable rises in sea level.



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upper, sunlit layer of the ocean and are most abundant along coastlines, in the Arctic, Antarctic, and near the equator. Zooplankton—very small or microscopic free-floating animals—and krill eat the phytoplankton, and are, in turn, eaten by larger animals.

Every spring in the cool waters off the coast of Antarctica, melting sea ice creates a layer of fresh water where the phytoplankton grow in large groups called blooms. Along the northern tip of the Antarctic Peninsula where warming temperatures have caused significant sea ice loss, phytoplankton blooms have been decreasing for several decades; while at the base of the peninsula, where the sea ice is not melting as quickly, the blooms have remained stable. Scientists would have expected increased sea ice loss to result in increased blooms, so this created an interesting question.

Through their research, scientists discovered that less sea ice around the tip of the peninsula led to more wind on the surface of the water. Additionally, the more intense wind (another result of climate change) was mixing the water, so the phytoplankton were no longer near the surface. The wind also blew in more clouds, which meant less sun energy for the phytoplankton to take in.

Scientists have also found that, in addition to smaller blooms, the type of phytoplankton had changed and no longer provided enough nutrition for the krill, which had moved to feed on the blooms at the base of the peninsula. As a result, the entire food web had begun to shift. Colonies of Adélie penguins, which eat primarily krill, had been replaced by other types of penguins, which do not rely on krill. Other climate effects, including sea ice decline, have also affected the decline of Adélie penguin populations in this area.

Beyond the northern tip of the Antarctic Peninsula and in addition to Adélie penguins, many sea animals

At Home on the Arctic Ice Floes

Sea ice covers much of the water around Alaska and northern Canada from October through June. Many animals use the sea ice for hunting, resting between dives, and giving birth to and caring for their young. Climate change is affecting not only the amount and location of sea ice, but also its thickness.

Not only do harp seals need solid ice to give birth and nurse their pups, the ice must be thick enough to hold up to the waves and weather. Ice that is too thin may break, separating pups from their mothers or dumping them into the water where they can be crushed between the chunks of ice.

Polar bears need solid ice to hunt for seals. Longer summer periods of ice-free days at sea means no ice platform for seals, and no hunting for bears.

Pacific walruses feed on the shellfish and invertebrates on the shallow sea floor of the Bering and Chukchi Seas. When sea ice is not available, they crowd onto small beaches in herds of up to 40,000.

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feed on krill, including fish, squid, birds, seals, and whales. Decreasing and shifting phytoplankton blooms, and the resulting shifts in krill populations, have the potential to disrupt the food web across the entire marine ecosystem.

In addition to its effects below the surface of the water, decreasing levels of sea ice are having a noticeable impact on the animals that live on and around it, including polar bears, seals, and walruses. Without sufficient sea ice on which to hunt, reproduce, and rest, species are having to swim farther, rest less, go hungry, concentrate in areas, and leave their young unattended more frequently.

Impact on Coastal Habitats

Coastal marine habitats, including river deltas, coral atolls, barrier islands, and beaches, are also under attack. Rising sea levels, more powerful tropical storms, and stronger storm surges are causing flooding, beach erosion, and saltwater intrusion. The nesting grounds of the world's largest sea turtle, the leatherback, are at risk of being flooded or washed away.

Although the full impact of changing ocean acidity is still being researched, shellfish and corals appear to be most immediately at risk. Through a chemical process, the higher acidity causes the shells of shellfish to become thinner and to grow more slowly.

At a certain acidity level, shells can even begin to dissolve. Shellfish are a significant source of food, and fewer or less healthy shellfish means less food for other animals, including human populations both locally and globally.

Coral reefs are being affected by increased ocean acidity and increased water temperatures. As a response to these factors, they can become "bleached" and seriously weakened. As a coral reef dies, its fish populations decline, resulting in less food for larger marine animals and humans. The loss of coral reefs also threatens the beaches and wetlands the reefs protect.

Finally, any change in the ocean currents has the possibility of significantly changing both the ocean and land. Currents distribute heat and other forms of energy, and upwelling supports large fish populations, which in turn support the marine food web and the commercial fishing industry

Rising temperatures are impacting the world's sea turtles at a time when six species are officially listed as endangered. Extensive beach erosion caused by rising sea level and more intense storms may increase threats to nesting beaches, where people and animals already prey on the eggs of marine turtles. Rising temperatures also increase the chance that sand temperature will exceed the upper limit for sea turtle egg incubation and impact the sex ratio toward females because temperature during incubation determines the sex of the egg. For example, Loggerhead turtle nests in Florida are already producing 90 percent females due to high temperatures.

IFAW researchers have already documented the early impact of climate change on whale populations in the Northern and Southern hemispheres and we have grave concerns that the dangers to whales will grow. In particular:

- The loss of food sources whales depend upon;
- Changes to the food web of the entire ocean;
- Impact on migratory paths and the consequences for their breeding grounds.


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Lesson 1: Convection Currents

Overview: Students will understand how temperature and salinity differences drive convection currents such as the Global Conveyor Belt.

Learning Outcomes:

Students will:

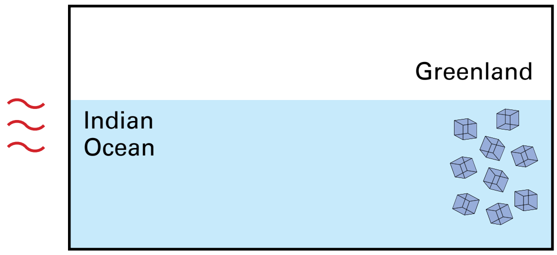
- Define a convection current.
- Explain the processes that create convection currents.

Instructional Time:
One 45-minute sessions

Materials:

- A glass aquarium
- Ice cubes made with colored water
- Hot plate (or other type of heater)
- Food coloring or ink
- Potassium permanganate crystals (if available)

Advance Preparation: Fill a glass aquarium with water to simulate the ocean. On the board, draw a picture of the aquarium, showing ice cubes and a coastline labeled "Greenland" on one side and the hot plate and a coastline labeled "Indian Ocean" on the other side.



Modeling a Convection Current

1. Ask students to reread the first paragraph under the "Ocean Processes at Work" heading and the sidebar "The Great Conveyor Belt" on page 2 of the Student Magazine. Tell students that you will use an aquarium to model the Global Conveyor Belt described in the reading.
2. Using your drawing for reference, explain that you will add ice cubes on one side of the aquarium to simulate the sinking of cold, salty water along the coast of Greenland and use the hot plate to heat the other side of the aquarium to simulate the rising branch of the Global Conveyor Belt in the Indian Ocean. Before proceeding, ensure that students understand the correspondence between each element of the ocean system and its counterpart in the aquarium.
3. Turn on the hot plate and wait a few minutes for the circulation to initiate.
4. After a few minutes, place the colored ice cubes in the "Greenland" side of the aquarium. Students will be able to see colored water sinking underneath the ice cubes.
5. To demonstrate the surface current, place a few droplets of food coloring or ink on the surface of the water in the middle of the aquarium and observe that the water moves from the warm side toward the cold side.
6. To demonstrate the bottom current, you can drop a few crystals of potassium permanganate into the water and observe the dark purple streams of color following the flow of bottom water from the cold side to the warm side.

NOTE: You need to act quickly, as the colors will quickly diffuse and mix in the water.

Demonstrating Understanding

1. Tell students that the aquarium modeled a convection current, which is caused in the ocean by differences in water temperature and salinity. Explain that in the ocean, the
cold water around the ice is also relatively salty, which makes the water even more dense and likely to sink.
2. Lead a discussion of students' observations and list them on the board. Discuss the processes that explain students' observations.
3. **Optional:** Have students create a diagram similar to the one on the board, and add their observations of the demonstration along with an explanation of the causes behind their observations.

Extending the Activity

Discuss with students the different mechanisms by which convection currents are altered. If needed, students can reread pages 2 and 3 of the Student Magazine to look for ideas.

- Discuss upwelling. Identify locations where upwelling occurs and ask students to brainstorm reasons why upwelling might occur in these places. (You can also expand the discussion to include downwelling.)
- Discuss the effect of melting ice near the poles or flood waters pouring into the ocean. Ask students to hypothesize how either of these might affect the Global Conveyor Belt, based on their understanding of convection currents.

Lesson 2: Ocean Acidity

Overview: Students will understand that carbon dioxide dissolves in water to make it more acidic. Students will also understand the effects of increased acidity on shellfish.

Instructional Time: **Three 45-minute sessions**

Learning Outcomes:

Students will:

- Use pH as a measure of acidity.
- Identify the effect of increased atmospheric CO_2 on ocean acidity.
- Explain the effect of increased ocean acidity on marine life.

Materials:

- Two small containers
- Shells from a shellfish (such as a mussel)
- pH indicator solution (or strips)
- Small clear glasses (at least 5 per student or group of students)
- Vinegar
- Clear liquid hand soap
- Drinking straws (1 per student)

Advance Preparation: At least a week prior to this lesson, fill two small containers: one with water and the other with an acidic solution. Be sure to store the containers in a safe place where they won't splash or spill. Containers with sealed lids can also help prevent accidental spills. Place a shell from a shellfish (a mussel shell works well) in each container. For best results, use a very strong acid and let it sit for at least two weeks. Always remember, safety first.

Measuring Acidity

1. Explain that the pH scale is used to measure the acidity of liquids. The scale ranges from a pH of 0 (the strongest acid solutions) to a pH of 14 (the strongest alkaline solutions), with "pure" water in the center with a pH of 7. Show the pH reading chart that corresponds to your indicator solution. Tell students that the colors correspond to different pH values and indicate the pH of the solution.
2. Have students individually or in small groups fill three glasses each about half full with water. Then have them pour some pH indicator into each of the glasses and identify what the color of the water means. (It will probably be neutral.)
3. Next have students pour some vinegar into one of the glasses and observe the change in color. Have students determine what the new color means. (The mixture has become more acidic.)
4. Finally, in a separate container, have students mix some liquid hand soap with a small amount of water. Then pour the soapy liquid into one of the remaining glasses (not into the glass with the vinegar) and observe the change in color. Have students determine what the new color means. (The mixture has become more alkaline.)
5. Have students add their results to Part 1 of **Worksheet 1** by coloring the appropriate squares and adding labels for "water," "vinegar solution," and "soap solution." Have them also use the pH indicator chart to determine and record the pH value of each liquid.
6. **Optional:** If time allows, you can challenge students to identify other clear liquids, then measure the pH and add it to the worksheet.

Dissolving CO_2

1. Remind students that the ocean and the atmosphere exchange carbon dioxide, and that increased CO_2 in the atmosphere also increases the amount of CO_2 absorbed by the ocean.
2. Tell students that they will demonstrate what happens when atmospheric carbon dioxide dissolves into the ocean. In this experiment, the ocean will be represented by water in a glass, and the atmospheric carbon dioxide will be simulated by blowing into the water with a straw (remind students that the air we exhale contains a lot of CO_2).
3. Have students fill two new glasses with water and add some pH indicator to each glass.
4. Then have students use their straws to blow into the water in one of the glasses.
5. After a few minutes, have students stop and note how the color of the water has changed. Have students compare the colors of their solutions, note the pH level, and explain the variations that exist between students' solutions. Have students record their results in Part 2 of the worksheet.
6. Reinforce the idea that as carbon dioxide dissolves in water, the water becomes more acidic and that this same process is happening in the ocean.

Discussing Effects on Shellfish

1. Show students your shellfish containers, explain what each contains, how long the shells have been immersed, and then carefully measure the pH of each solution. Model appropriate use of safety equipment for students. Point out that the ocean is not as acidic as your solution, but that the experiment was designed to more quickly observe the long-term results of increased ocean acidity.
2. Rinse and dry each shell thoroughly. Have students examine the two shells and note their observations on Part 3 of the worksheet.
3. After students have made their observations, lead a discussion about the implications of the experiment for marine life. Students should understand that it is more difficult for shellfish and corals to grow a shell in an acidic environment, and that they also grow more slowly.

Worksheet 1: Measuring Acidity

Name: ____ Date: __________________________

← Acidic — Neutral — Alkaline →

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14

Part 1:

Water pH _____

Vinegar Solution pH _____

Soap Solution pH _____

Other solutions:

_______________________ pH _____

_______________________ pH _____

_______________________ pH _____

Part 2:

Water pH _____ CO_2 solution pH _____

How does my CO_2 solution compare to others in the class?

Possible reasons for the variation:

Part 3:

Water pH _____ Acidic solution pH _____

Duration _____ days

Observations:

Implications for marine life: